AMS-151

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

EXPERIMENTS ON DISTRIBUTING LIQUID FUMIGANTS IN BULK GRAINS WITH AERATION SYSTEMS

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SUMMARY

This is the third in a series of reports presenting the results of tests to distribute fumigants in bulk grain with existing mechanical aeration systems, at airflow rates used in cooling grain. This report deals with tests made with liquid fumigants.

In three tests in grain elevator tanks more than 100 feet deep, the vapors of liquid fumigants were effectively distributed either by recirculation or by drawing the vapors down through the grain mass until a satisfactory concentration was measured at the bottom. In one test, the vapors were redistributed by reversing the airflow and pushing the vapors back to the surface layer every 24 hours.

In four tests in large steel storage tanks 96 feet in diameter and 30 feet high, the vapors were satisfactorily distributed by recirculation at the start of the fumigation, and redistributed by an upward airflow for a short time when they had settled out of the surface layer.

In eight tests in upright 10,000-bushel steel storage tanks, distribution by recirculation did not appear to be much better than distribution by gravity penetration.

1/This is one of the field stations of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

Agriculture-Washington

January 1957

INTRODUCTION

This report, the third in a series, 2/ describes the results of tests to distribute liquid fumigants in bulk grain by the use of existing mechanical aeration systems, at airflow rates used in cooling grain.3/ Liquid fumigant mixtures are those which are liquid at normal temperatures and are not handled in pressure containers.

Three tests were made in grain elevator tanks at Danville, Ill., and Sterling and Garden City, Kans. Four tests were made in large steel storage tanks at Neodesha, Kans. Eight tests were conducted in upright steel tanks at Verden, Okla. The results will be grouped under headings according to these three types of structures.

TECHNIQUE

In the tests at Danville, Sterling, Garden City, and Neodesha, evaluation of results was based upon gas analysis alone. In the tests at Verden, insect samples also were used.

Gas sampling technique

The same procedure for placing gas sampling tubes was followed as reported in the previous papers (see footnote 2). In grain elevator tanks, the tubes were formed into cables, with tubes terminating at selected levels in the tank. Three or more cables were installed vertically in each tank before it was filled, by anchoring them to existing vertical temperature cables or to $\frac{1}{4}$-inch steel cables installed for this purpose.

2/Grain fumigation. Agric. Chem. X(1):55-56, 117-121: X(2):41-43, 133, 135, Jan. Feb. 1955: Experiments on distributing methyl bromide in bulk grains with aeration systems, AMS 150.

3/The tests were a cooperative endeavor with the Dow Chemical Company and Michigan Chemical Corporation. Acknowledgments are due C. S. Bulger and W. Keith Whitney, of the Stored-Grain Insects Laboratory, for assistance in some of the tests; to G. L. Kline and Harry Converse, engineers with the Manhattan Field Office, Handling and Facilities Research Section, Agricultural Marketing Service; to R. L. Parker, entomologist with the Lauhoff Grain Company, for assistance in tests made at Danville, Ill., and to members of the technical and field staffs of the cooperating companies. Sites were made available for the tests by the Lauhoff Grain Company, Danville, Ill.; Farmers Union Co-op Elevator, Sterling, Kans.; Garden City Co-op Equity Exchange, Garden City, Kans.; Moore-Stauffer Company, Verden, Okla.; and Emergency Grain Storage Company, Neodesha, Kans.

In the large steel tank and upright steel tank storage, probes were inserted from the top surface. At each selected sampling station, several probes were used, each one inserted to a different depth in the grain—for example, 1 to 10 feet, 1 to 20 feet, and 1 to 30 feet.

The concentrations of gas were determined with the thermal-conductivity gas analyzer. Since the instrument indicated the total gas present, and since no technique was available to separate the components of the fumigant mixtures, the readings are in terms of units on the galvanometer scale. These are valuable to indicate the comparative gas concentrations at the sampling points. It was realized that the ratio of the components could have been different than their proportion in the liquid mixture at any reading as a gas. Since this is a study on distribution, the galvanometer readings were considered to be a satisfactory criterion for evaluation.

The time pattern established in previous tests was followed for sampling, that of ½, 2, 4, 8, and 24 hours. Subsequent sampling was dependent upon the type of test under way.

Test insect samples

Samples of test insects were placed at two locations in the tanks at Verden, at the center and near one wall. At each location cages were placed above the grain (resting on the grain surface) and at depths of 2, 4, and 12 feet. The cages were placed in steel probes, and the probes inserted to the desired depth. Granary weevil adults and immature stages, and flour beetle adults were used.

After fumigation, the insects were placed in clean cages and held for observation of mortality. Samples containing the immature stages of the granary weevil were held under optimum development conditions from four to six weeks to observe adult emergence, if any.

TESTS IN GRAIN ELEVATOR TANKS

These tests were made parallel with, and at the same installations as the tests with methyl bromide described in the second report of this series, to determine whether liquid fumigant mixtures could be applied by the recirculation and forced distribution methods.

Test H-1 was conducted in April 1955 in the test elevator at Danville, Ill., which had been equipped with a recirculation system. This system was fully described in the first report of this series. In this test, the vapors were recirculated.

The tank was filled with shelled corn for this test, and the blower produced an airflow rate of 0.022 c.f.m./bu.

The fumigant used was one of the standard mixtures containing 29.2 percent ethylene dichloride, 63.6 percent carbon tetrachloride, and 7.2 percent ethylene dibromide, by weight. It was applied at the rate of 1.4 gallons per 1,000 bushels as a spray on the top surface, following which the blower was started and the vapors recirculated downward, until readings on the gas analyzer indicated a fairly uniform distribution. The blower was operated 1 hour to accomplish this. At the 24-, 48-, 72-, and 96-hour periods, the vapors were again recirculated by operating the blower for 40 minutes each time. After the desired exposure period, the fumigant vapors were removed by operating the aeration system.

Gas sampling tubes were assembled in 3 cables, 1 down the center, 1 near the north wall, and 1 near the south wall. Samples were taken at the surface, 15-, 35-, 55-, 75-, 95-, and 115-foot depths, and in the hopper.

The results are presented in table 1. It may be noted that the concentration was heavier in the bottom half of the tank after the initial application by recirculation, and that the pattern did not change appreciably during the first 24 hours. When the vapors were recirculated at the 24-hour period, the distribution was improved. In the second 24 hours, the concentrations in the top half dropped again, but remained about the same in the bottom half. A second recirculation improved the distribution somewhat. In the third and fourth 24 hours, the distribution remained fairly stable, and the third and fourth recirculations produced very little change.

Test H-2 was conducted during October 1955 in an elevator tank at Sterling, Kans., similar to the one described in the second report of this series. In this test, the aeration system was not modified. The vapors were distributed by drawing them down through the grain mass until a satisfactory concentration was present at the bottom.

The tank was 105 feet high and 26 feet in diameter, and contained 47,000 bushels of wheat. The aeration system consisted of a half-round duct in the center of the flat floor of the bin, connected to a blower driven by a 7½-hp. motor. The airflow rate was 0.04 c.f.m./bu.

The fumigant mixture used in this test was composed of 64.6 percent ethylene dichloride, 27.4 percent carbon tetrachloride, 5 percent ethylene dibromide, and 3 percent sulfur dioxide. It was applied at a dosage rate of 2 gallons per 1,000 bushels of wheat, to the top surface of the grain, as a coarse spray. The blower was started after the fumigant was applied, and operated for the length of time necessary for one air change in the tank, 14 minutes. The air from the blower was discharged to the outer air, and not recirculated in this instance. The exposure period was 96 hours.

Sampling tubes were assembled in 3 cables, 1 down the center, 1 near the north wall, and 1 near the south wall. Samples were withdrawn from the surface, and at depths of 11, 29, 47, 65, 83, and 101 feet.

The results of vapor distribution are presented in table 2. The distribution from the initial operation of the aeration system was quite good except at the 101-foot depth. This was adjusted by gravity settling by the 24-hour period, but, oddly enough, the concentration fell again at this level after it had adjusted itself. It had been intended to redistribute the fumigant vapors every 24 hours by reversing the direction of the blower and forcing the vapors upward to the top. The distribution was so adequate that this was not necessary.

Test H-3 was conducted at Garden City, Kans., in October 1955 in the same tank used in a test at this establishment with methyl bromide, reported in the second report of the series. In this test also the established aeration system was not modified, and the fumigant vapors were drawn down through the grain mass until a satisfactory concentration was obtained at the bottom.

The tank was 101 feet high and 18 feet in diameter, and was equipped with a hopper bottom. The aeration system consisted of a half-round duct at the top center of the hopper, connected to a blower driven by a 3-hp. motor which produced an airflow rate of 0.049 c.f.m./bu.

The same fumigant mixture was used as in test H-2 at Sterling, and applied at the rate of 2 gallons per 1,000 bushels of wheat. The fumigant mixture was sprayed on the top surface of the grain. Then the blower was operated for the length of time necessary for one air change, 10 minutes. The air from the blower was discharged into the outside. The exposure period was 72 hours.

Sampling tube cables were fastened to 4 temperature cables already installed in the tank, 1 down the center, and 1 about 5 feet from the wall in the north, east, and south quadrants. Samples were withdrawn from the headspace, the hopper, and at 8-, 26-, 44-, 62-, 80-, and 98-foot depths in the grain. The results are presented in table 3. The initial distribution was very good except in the hopper. Since the vapors were still well distributed after 24 hours, original plans to redistribute them by reversing the direction of the fan were abandoned. The distribution remained fairly constant through the 72 hours except in the headspace and in the bottom at the 98-foot depth.

It was concluded from this series of tests that the distribution of vapors of liquid fumigants could be accomplished by utilizing existing aeration systems either to recirculate the vapors, or to distribute them initially by drawing them down through the grain mass until an adequate concentration was obtained at the bottom. The distribution procedure necessitated a calculation of the time required to change the air content once, and a means of determining the vapor concentrations to guide the operation of the blower.

Table 1.--Distribution of the vapors of a liquid fumigant in an elevator tank of shelled corn resulting from recirculation for one hour with an airflow rate of 0.022 c.f.m./bu., and subsequent redistribution each 24 hours by operating the blower in reversed position for 40 minutes

Sample location and number	Galvanometer readings following recirculation				Galvanometer readings before and after redistribution							
					24 hours		48 hours		72 hours		96 hours	
	½ hour	2 hours	4 hours	8 hours	before	after	before	after	before	after	before	after
	Units	Units	Units	Units	Units	Units	Units	Units	Units	Units	Units	Units
Headspace												
1. Above load	5	4	3	3	7	10	6	10	3	10	6	6
15 feet deep												
2. North wall	2	4	4	4	6	6	0	2	0	2	2	2
3. Center	7	5	4	6	4	18	5	7	10	8	8	6
4. South wall	3	2	4	2	1	12	1	4	3	2	3	1
35 feet deep												
5. North wall	1	2	2	2	0	4	2	2	2	4	2	3
6. Center	10	7	8	8	8	19	10	12	18	10	10	6
7. South wall	2	2	2	3	2	10	2	4	3	4	2	2
55 feet deep												
8. North wall	2	2	2	3	3	4	2	3	3	4	2	2
9. Center	14	12	12	14	10	30	14	15	16	16	12	10
10. South wall	3	2	3	3	2	8	2	3	2	4	2	2
75 feet deep												
11. North wall	3	4	4	4	4	5	5	6	4	6	3	4
12. Center	16	10	10	19	14	24	17	17	12	20	16	9
13. South wall	10	6	6	6	4	10	5	5	4	4	2	3
95 feet deep												
14. North wall[1/] . . .	7	9	10	12	11	12	12	14	10	10	5	5
15. Center[1/]	46	42	42	42	34	33	23	24	20	16	18	12
16. South wall	10	8	8	7	5	14	5	7	5	7	9	6
115 feet deep												
17. North wall	24	23	20	15	15	11	15	15	10	10	10	6
18. Center[1/]	82	83	87	55	55	64	42	28	20	20	20	12
19. South wall[1/] . . .	10	10	12	34	34	16	16	12	10	10	8	6
20. Hopper	16	16	12	2	2	8	5	8	2	6	8	4

1/Sample tubes Nos. 14, 15, 18, and 19 were broken so the exact location of these samples is not known.

Table 2.--Distribution of the vapors of a liquid fumigant in an elevator tank of wheat resulting from distribution by operating the aeration blower for 14 minutes at an airflow rate of 0.04 c.f.m./bu. in order to distribute the vapors from top to bottom of the tank

Sample location and number	Galvanometer readings following the initial distribution							
	½ hour	2 hours	4 hours	8 hours	24 hours	48 hours	72 hours	96 hours
	Units	Units	Units	Units	Units	Units	Units	Units
North side								
1. Above load	24	20	24	18	9	10	4	3
2. 11 feet deep	40	82	120	85	76	64	58	56
3. 29 feet deep	44	75	124	80	82	60	54	52
4. 47 feet deep	104	85	104	116	64	54	47	46
5. 65 feet deep	70	66	70	120	56	38	14	26
6. 83 feet deep	50	31	32	90	72	34	13	20
7. 101 feet deep	36	4	4	20	65	38	14	2
Center								
8. Above load	31	64	78	86	62	37	32	32
9. 11 feet deep	72	86	104	70	74	56	56	52
10. 29 feet deep	80	86	84	90	78	56	50	52
11. 47 feet deep	68	86	78	68	68	48	47	43
12. 65 feet deep	108	84	96	46	43	55	48	42
13. 83 feet deep	86	80	80	60	50	51	46	18
14. 101 feet deep	0	0	0	6	43	42	0	3
South side								
15. Above load	34	68	80	44	66	48	48	48
16. 11 feet deep	24	35	40	64	76	38	40	38
17. 29 feet deep	46	50	54	62	54	43	43	42
18. 47 feet deep	64	64	62	84	54	40	42	35
19 65 feet deep	70	70	70	90	60	42	38	32
20. 83 feet deep	60	24	26	58	46	32	18	13
21. 101 feet deep	4	4	0	4	48	0	0	2

Table 3.--Distribution of the vapors of a liquid fumigant in an elevator tank of wheat resulting from distribution by operating the aeration blower for 10 minutes at an airflow rate of 0.049 c.f.m./bu. in order to distribute the vapors from top to bottom of the tank

Sample location and number	Galvanometer readings following the initial distribution						
	½ hour	2 hours	4 hours	8 hours	24 hours	48 hours	72 hours
	Units	Units	Units	Units	Units	Units	Units
North side							
1. Above load	12	7	4	4	10	6	4
2. 8 feet deep	90	108	116	75	40	14	8
3. 26 feet deep	82	102	114	108	66	46	40
4. 44 feet deep	94	88	74	60	48	37	30
5. 62 feet deep	90	70	60	44	34	24	20
6. 80 feet deep	70	55	46	33	26	14	16
7. 98 feet deep	34	34	26	18	22	21	8
8. In hopper	T	2	4	6	12	6	5
East side							
9. Above load	30	14	14	15	11	7	4
10. 8 feet deep	26	40	40	42	38	26	24
11. 26 feet deep	86	74	82	92	40	39	37
12. 44 feet deep	48	34	36	30	30	24	22
13. 62 feet deep	46	32	32	27	25	20	19
14. 80 feet deep	44	30	30	24	20	16	15
15. 98 feet deep	12	24	28	23	20	10	8
South side							
16. Above load	4	7	7	6	14	7	5
17. 8 feet deep	28	30	30	26	18	10	6
18. 26 feet deep	14	22	28	55	34	30	26
19. 44 feet deep	32	26	26	32	40	32	27
20. 62 feet deep	36	30	30	30	35	30	25
21. 80 feet deep	20	20	20	20	22	12	10
22. 98 feet deep	40	34	30	27	20	5	3
Center							
23. Above load	10	6	13	10	15	7	5
24. 8 feet deep	70	116	116	104	44	26	18
25. 26 feet deep	120	144	144	144	80	44	50
26. 44 feet deep	84	124	124	120	97	68	56
27. 62 feet deep	92	100	96	92	80	62	50
28. 80 feet deep	64	75	68	70	52	40	33
29. 98 feet deep	44	38	37	42	16	7	4

TESTS IN LARGE STEEL STORAGE TANKS

Four tests were made in tanks loaded with wheat at Neodesha, Kans., in September 1954. Each tank was 96 feet in diameter and 30 feet high, and contained more than 100,000 bushels of wheat. The wheat temperatures ranged from 74° to 97°F.

The aeration systems were identical. Each consisted of two halves, with a main duct running from one wall to the center, and with laterals to the tank periphery on each side, and a duplicate but separate system in the other half (fig. 1). A blower was connected to each main duct. The same pair of blowers was used on all tanks, and they were mounted on trucks and operated by power take off from the truck motor (fig. 2). Each blower had a capacity of approximately 10,500 c.f.m. under operating conditions, producing airflow rates ranging between 0.075 and 0.095 c.f.m./bu., depending on the size of load. A portable return duct was installed on each blower so that each aeration system was converted to a recirculation system. The fumigant vapors were recirculated in all four tests.

Tests I-1, I-2, and I-3 were replicates of each other. Gas sampling probes were inserted to depths of 1, 10, 20, and 30 feet at 3 locations in the tanks at the center, west wall, and center of east half.

A fumigant mixture containing 80 percent carbon tetrachloride and 20 percent carbon disulfide (by volume) was applied in each tank at a rate of 1½ gallons per 1,000 bushels. The mixture was applied to the top surface of the grain as a coarse spray. From 2 to 4 hours were required to apply the fumigant because of the small pumps used. As soon as the application was complete, the blowers were started and operated until a high concentration was present at the floor level. This period ranged from 15 to 20 minutes of blower operation.

The exposure periods varied from 11 days in test I-3, to 13 days in test I-2 and 14 days in test I-1.

Test I-4 was conducted in the same manner except that a fumigant mixture was used consisting of 10 percent acrylonitrile and 90 percent carbon tetrachloride (by volume).

At the end of the exposure period in each test, an attempt was made to redistribute the vapors by operating the blower in a reverse direction for a short period.

The results for test I-1 are presented in table 4. The initial distribution was satisfactory in spite of the long period required to apply the dosage of fumigant. The concentration in the headspace fell off rapidly and was zero by the 8-hour period. The concentration one foot below the surface declined after the second day. For some unexplainable reason, sample location 2 in the center at the 20-foot depth, was low all through the test. When the blowers were operated in a reversed position for 6 minutes on the 14th day, the concentration at the surface and in the headspace was brought up to a satisfactory level.

The results for test I-2 are given in table 5. Here again the initial distribution was satisfactory, and remained that way except in the surface layer at the center and east side, through the 13th day. The operation of the blower in reversed position raised the concentration in the headspace and surface layer to a satisfactory level.

The results of test I-3 are presented in table 6. The 20-foot depth at the center was again an area of low concentration, but otherwise the distribution was quite satisfactory. The surface and headspace concentrations were brought back to a satisfactory level on the 11th day by the 6-minute operation of the blower in reversed position.

The results of test I-4 with the acrylonitrile-carbon tetrachloride mixture are given in table 7. The original distribution was satisfactory, and remained that way except in the surface layer through the 12-day exposure. The concentrations in the headspace and surface layer were restored by operating the blowers to force the vapor up from the lower levels in the grain.

These tests demonstrated further that satisfactory distribution of the vapors of liquid fumigants can be obtained by recirculating them after application of the fumigant in liquid form to the grain surface. It was also shown that, as the vapors settled out of the surface layers, they could be redistributed by an upward airflow for a short time.

Table 4.--Distribution of the vapor of a liquid fumigant in a large steel storage tank of wheat, resulting from recirculation for 15 minutes at an airflow rate of approximately 0.8 c.f.m./bu., test I-1

Sample location and number	Galvanometer readings[1] during exposure period								
	½ hour	2 hours	4 hours	8 hours	24 hours	48 hours	72 hours	96 hours	14 days
	Units	Units	Units	Units	Units	Units	Units	Units	Units
Center									
1. 1 foot deep . . .	112	77	73	64	39	13	0	0	5[2]
2. 10 feet deep . . .	123	83	80	72	37	13	0	0	5
3. 20 feet deep . . .	7	3	0	0	0	0	0	0	0
4. 30 feet deep . . .	56	35	37	37	56	59	43	43	10
Midway east side									
5. 1 foot deep . . .	56	32	29	29	33	19	0	0	5[2]
6. 10 feet deep . . .	123	117	115	96	61	44	11	16	10
7. 20 feet deep . . .	123	67	63	56	63	48	28	35	8
8. 30 feet deep . . .	101	83	80	75	88	57	36	40	10
Wall west side									
9. 1 foot deep . . .	131	131	127	61	51	32	8	16	5[2]
10. 10 feet deep . . .	135	128	88	85	120	76	52	45	7
11. 20 feet deep . . .	128	120	107	69	32	20	0	0	8
12. 30 feet deep . . .	131	112	101	69	35	16	5	0	8
Headspace									
13	13	13	7	0	0	0	0	0	0[2]

1/In this instance, the galvanometer readings approximate ounces/1,000 cu. ft. based on a tentative calibration of the gas analyzer for this mixture.

2/Concentrations raised in surface layer and headspace to 12, 10, 12, and 10 units, respectively, by operation of blowers for 6 minutes in reversed position.

Table 5.--Distribution of the vapor of a liquid fumigant in a large steel storage tank of wheat, resulting from recirculation for 19 minutes at an airflow rate of approximately 0.8 c.f.m./bu., test I-2

Sample location and number	Galvanometer readings 1/during exposure period							
	½ hour	2 hours	4 hours	8 hours	24 hours	48 hours	72 hours	13 days
	Units	Units	Units	Units	Units	Units	Units	Units
Center								
1. 1 foot deep	141	139	125	93	32	4	11	8 2/
2. 10 feet deep	155	125	120	117	99	61	57	26
3. 20 feet deep	75	59	36	36	24	24	23	19
4. 30 feet deep	101	97	72	75	80	59	77	34
Midway north side								
5. 1 foot deep	203	219	189	128	40	16	25	12 2/
6. 10 feet deep	75	97	91	80	28	80	80	30
7. 20 feet deep	267	267	267	240	171	88	83	8
8. 30 feet deep	139	114	91	96	171	112	115	44
Wall east side								
9. 1 foot deep	173	165	131	80	16	0	4	4 2/
10. 10 feet deep	123	117	91	75	67	43	53	30
11. 20 feet deep	80	91	77	69	43	37	48	30
12. 30 feet deep	116	88	72	64	40	29	37	26
Headspace								
13.	128	80	59	53	20	0	4	0 2/

1/In this instance, the galvanometer readings approximate ounces/1,000 cu. ft. based on a tentative calibration of the gas analyzer for this mixture.

2/Concentrations raised in surface layer and headspace to 24, 30, 30, and 24 units, respectively, by operation of blowers for 6 minutes in reversed position.

Table 6.--Distribution of the vapor of a liquid fumigant in a large steel storage tank of wheat, resulting from recirculation for 15 minutes at an airflow rate of approximately 0.8 c.f.m./bu., test I-3

Sample location and number	Galvanometer readings[1] during exposure period					
	½ hour	2 hours	4 hours	8 hours	24 hours	11 days
	Units	Units	Units	Units	Units	Units
Center						
1. 1 foot deep	240	221	144	117	27	20[2]
2. 10 feet deep	209	80	83	80	64	20
3. 20 feet deep	13	0	0	0	0	0
4. 30 feet deep	267	280	267	261	187	20
Midway east side						
5. 1 foot deep	181	168	115	75	21	6[2]
6. 10 feet deep	181	176	219	229	141	28
7. 20 feet deep	133	173	142	147	128	26
8. 30 feet deep	193	168	155	213	125	20
Wall east side						
9. 1 foot deep	267	213	163	120	33	10[2]
10. 10 feet deep	173	227	160	135	123	22
11. 20 feet deep	267	168	208	171	107	22
12. 30 feet deep	224	176	252	213	171	36
Headspace						
13.	147	120	75	64	16	5[2]

1/In this instance, the galvanometer readings approximate ounces/1,000 cu. ft. based on a tentative calibration of the gas analyzer for this mixture.

2/Concentrations raised in surface layer and headspace to 24, 24, 30, and 18 units, respectively, by operation of blowers for 6 minutes in reversed position.

Table 7.--Distribution of the vapor of a liquid grain fumigant in a large steel storage tank of wheat, resulting from recirculation for 20 minutes at an airflow rate of approximately 0.8 c.f.m./bu., test I-4

Sample location and number	Galvanometer readings[1] during exposure period						
	½ hour	2 hours	4 hours	8 hours	24 hours	48 hours	12 days
	Units	Units	Units	Units	Units	Units	Units
Center							
1. 1 foot deep	4	0	3	3	0	0	2[2]
2. 10 feet deep	176	124	86	70	50	38	16
3. 20 feet deep	86	86	74	63	48	42	12
4. 30 feet deep	200	200	196	200	82	70	10
Midway west side							
5. 1 foot deep	200	120	85	60	6	4	3[2]
6. 10 feet deep	64	56	50	50	60	60	32
7. 20 feet deep	100	116	160	134	70	44	14
8. 30 feet deep	120	186	180	200	90	86	7
Wall north side							
9. 1 foot deep	90	68	56	50	38	28	4[2]
10. 10 feet deep	90	66	64	50	38	36	24
11. 20 feet deep	80	64	56	48	40	35	10
12. 30 feet deep	80	54	48	44	44	46	10
Headspace							
13.	96	64	60	54	10	7	4[2]

1/In this instance, the galvanometer readings approximate ounces/1,000 cu. ft. based on a tentative calibration of the gas analyzer for this mixture.

2/Concentrations raised in surface layer and headspace to 10, 10, 16, and 12 units, respectively, by operation of blowers for 6 minutes in reversed position.

TESTS IN UPRIGHT STEEL TANKS

These tests were made during November 1954 at Verden, Okla., in eight 10,000-bushel upright steel tanks similar to those used for methyl bromide tests described in the second report of the series. Two series of tests were made, each using a different fumigant mixture, and in each series the recirculation method was compared with gravity penetration of the vapors.

Each tank was 32 feet high, 21 feet in diameter, and was filled with wheat. The aeration system consisted of a central hub on the floor, 4 feet in diameter with 16 laterals leading to the walls. A detailed description was given in the earlier publication. The blower was equipped with a return duct to the headspace, and the airflow rate was determined to be 0.18 c.f.m./bu.

Gas sampling probes were placed to draw samples from the headspace and from depths of 6, 12, 20, and 30 feet in each tank. Insect samples were placed on the surface and at depths of 2, 4, and 12 feet at 2 locations in each tank.

In tests J-1, J-2, J-3, and J-4, an experimental mixture known as Dow M-406, which contained carbon tetrachloride, ethylene dichloride, and other ingredients, was applied at the rate of $1\frac{1}{2}$ gallons per 1,000 bushels. In tests J-1, J-2, and J-3, the blower was started after the fumigant had been applied as a coarse spray to the top surface of the grain, and the vapors were recirculated until a satisfactory distribution was registered on the gas analyzer unit. This required from 4 to 7 minutes operation of the blower. After 24 hours, the blower was operated for 4 minutes in reversed position to redistribute the vapors. In test J-4, the fumigant was applied to the grain surface and the vapors were distributed by gravity penetration. The exposure period was 48 hours.

In tests J-5, J-6, J-7, and J-8, a standard fumigant mixture was used composed of 29.2 percent ethylene dichloride, 63.6 percent carbon tetrachloride, and 7.2 percent ethylene dibromide, by weight. In the first three tests, the fumigant was applied to the grain surface, then recirculated for 6 to 13 minutes until satisfactory distribution was obtained. After 24 hours, the vapors were redistributed by operating the blower in reversed position for 4 minutes. In test J-8, the fumigant was applied to the grain surface and the vapors were distributed by gravity penetration. The exposure period was 48 hours in all instances.

The results of tests J-1 to J-4 are given in tables 8, 9, and 10. The average distribution at the end of the initial recirculation period was not very uniform, the concentrations being high at 12 feet and deeper. The concentrations in the headspace and at the 6-foot depth continued to decrease during the rest of the 24-hour period. The redistribution after 24 hours raised the concentration in the headspace to a satisfactory level. The distribution by gravity penetration showed a high concentration at the 6-, 12-, and 20-foot depths at 6 hours, and at the 12- and 20-foot depths at 24 hours. However, the insect mortality was complete at all locations in test J-4, but some granary weevil eggs or larvae survived at all levels where the vapors were recirculated.

The results of tests J-5 to J-8 are given in tables 11, 12, and 13. The average distribution at the end of the initial circulation period was good except at the 30-foot depth, and this was partially corrected during the first 24 hours. The concentration in the headspace remained at a good level. The redistribution at 24 hours resulted in quite comparable concentrations in the headspace and at the 30-foot depth. On the other hand, the concentrations in test J-8 resulting from gravity penetration appeared to be quite low. After 24 hours, the concentration in the headspace and at the 6-foot depth were very low.

Survival of test insects was low in the tests where the vapors were recirculated, occurring at the 4- and 12-foot depths. Some granary weevil eggs or larvae survived in the headspace and at 4- and 12-foot depths in test J-8.

It was concluded from these tests that, in this size of storage tank, the distribution by recirculation did not produce appreciably better insect mortality than did distribution by gravity penetration. The dosage rate used of each fumigant mixture appeared to be marginal for larvae of the granary weevil.

Table 8.--Distribution of the vapors of liquid fumigant M-406 in a 10,000-bushel upright steel storage tank of wheat resulting from recirculation for 4 to 7 minutes at an airflow rate of 0.18 c.f.m./bu. with a dosage rate of 1½ gals./1,000 bu., and redistribution after 24 hours, average of 3 tests, J-1, J-2, and J-3

Sample location and number	Galvanometer readings after recirculation					Galvanometer readings after redistribution
	½ hour	2 hours	4 hours	8 hours	24 hours	
	Units	Units	Units	Units	Units	Units
1. Headspace	127	91	96	55	19	76
2. 6 feet deep	107	105	55	49	46	
3. 12 feet deep	227	159	147	205	141	
4. 20 feet deep	216	150	134	97	78	
5. 30 feet deep	245	264	195	178	203	180

Table 9.--Distribution of the vapors of liquid fumigant M-406 in a 10,000-bushel upright steel tank of wheat resulting from gravity penetration with a dosage rate of 1½ gals./1,000 bu., test J-4

Sample location and number	Galvanometer readings after	
	6 hours	24 hours
	Units	Units
1. Headspace	32	44
2. 6 feet deep	184	52
3. 12 feet deep	184	196
4. 20 feet deep	168	166
5. 30 feet deep	76	88

Table 10.--Average mortality of test insects resulting from fumigation with liquid fumigant M-406 recirculated for 4 to 7 minutes at an airflow rate of 0.18 c.f.m./bu. with a dosage rate of 1½ gals./1,000 bu. and an exposure period of 48 hours, compared with distribution by gravity penetration, tests J-1, J-2, J-3, and J-4

Fumigant recirculated

Depth in grain	Granary weevil adults	Granary weevil eggs or larvae	Flour beetle adults
	Percent	Percent	Percent
1. Headspace	100	99.5	100
2. 2 feet deep	100	95.5	100
3. 4 feet deep	100	89.5	100
4. 12 feet deep	100	94.0	100

Fumigant distributed by gravity penetration

5. Headspace	100	100	100
6. 2 feet deep	100	100	100
7. 4 feet deep	100	100	100
8. 12 feet deep	100	100	100

Table 11.--Distribution of the vapors of a liquid fumigant in a 10,000-bushel storage tank of wheat resulting from recirculation for 6 to 13 minutes at an airflow rate of 0.18 c.f.m./bu. with a dosage rate of 1½ gals./1,000 bu. and redistributed after 24 hours, average of 3 tests, J-5, J-6, and J-7

Sample location and number	Galvanometer readings after recirculation					Galvanometer readings after redistribution
	½ hour	2 hours	4 hours	8 hours	24 hours	
	Units	Units	Units	Units	Units	Units
1. Headspace	108	88	61	59	35	80
2. 6 feet deep	200	200	184	176	158	
3. 12 feet deep	206	194	199	139	157	
4. 20 feet deep	165	135	157	151	144	
5. 30 feet deep	67	42	100	111	99	87

Table 12.--Distribution of the vapors of a liquid fumigant in a 10,000-bushel upright tank of wheat resulting from gravity penetration with a dosage of 1½ gals./1,000 bu., test J-8

Sample location and number	Galvanometer readings after	
	5 hours	24 hours
	Units	Units
1. Headspace	8	0
2. 6 feet deep	38	10
3. 12 feet deep	50	80
4. 20 feet deep	54	40
5. 30 feet deep	no sample, probe broken	

Table 13.--Average mortality of test insects resulting from fumigation with a liquid fumigant recirculated for 6 to 13 minutes at an airflow rate of 0.18 c.f.m./bu. with a dosage rate of 1½ gals./1,000 bu. and an exposure period of 48 hours, compared with distribution by gravity penetration, tests J-5, J-6, J-7, and J-8

Fumigant recirculated

Depth in grain	Granary weevil adults	Granary weevil eggs or larvae	Flour beetle adults
	Percent	Percent	Percent
1. Headspace	100	100	100
2. 2 feet deep	100	100	100
3. 4 feet deep	100	99.5	100
4. 12 feet deep	99.0	98.0	100

Fumigant distributed by gravity penetration

5. Headspace	100	92	100
6. 2 feet deep	100	100	100
7. 4 feet deep	100	92	100
8. 12 feet deep	90.5	66.5	100

Neodesha Tanks

Diameter - 96 feet

Wall Height - 30 feet

Cone Height - 5 feet

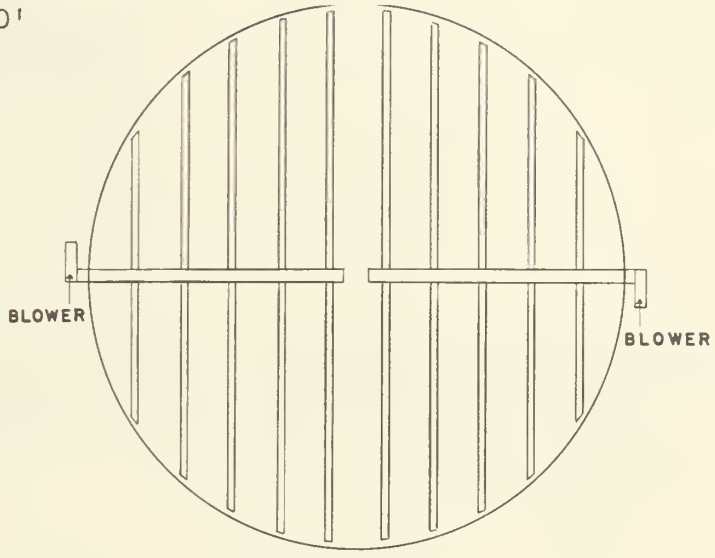
Total Height - 35 feet

Headspace

Surface

10, 20, 30 feet deep

Scale - 7/16" = 10'



BN-3656

Figure 1.--Diagram of aeration system in large steel storage tanks showing floor ducts.

BN-3657

Figure 2.--View of portable blower unit attached to aeration system in one of the steel storage tanks used in the tests.

PREVIOUS ISSUES OF THIS SERIES RELATED TO STORED-PRODUCT INSECTS

AMS-4. Fumigation of dry beans and cowpeas on the packaging line. January 1955.

AMS-5. Procedure for the fumigation of dry beans and cowpeas on the packaging line. January 1955.

AMS-49. Timing of sprays to control the cigarette beetle. May 1955.

AMS-58. An insect preventive program for peanut warehouses. June 1955.

AMS-64. Protecting stored seed from insect attack. (Revision of former Bureau of Entomology and Plant Quarantine publication E-677, issued December 1945.) July 1955.

AMS-73. Effect of varying the volatilization of methyl bromide by combinations with various solvents on its distribution in bulk grain fumigation. December 1955.

AMS-101. Studies on separation of weevil-infested from noninfested wheat by flotation. March 1956.

AMS-131. Enclosures for fumigating stored raisins. July 1956.

AMS-150. Experiments on distributing methyl bromide in bulk grain with aeration system. February 1957.